[0003] In another embodiment, a method for etching features formed on a substrate is provided. The method may comprise providing a substrate having a high aspect ratio structure comprised of a first set of exposed features comprising silicon nitride, and a second set of exposed features comprising silicon or silicon oxide. The method further comprises loading the substrate into a wet chemical processing system. The method further comprises two etch steps: performing a first etch step comprised of exposing the substrate to a first wet etch chemical composition to remove at least part of the silicon nitride from the high aspect ratio structure, the exposing the substrate to a first wet etch chemical composition forming silicon containing deposits on the silicon or silicon oxide of the high aspect ratio structure; and performing a second etch step comprised of exposing the substrate to a second wet etch chemical composition to remove at least some of the silicon containing deposits formed on the silicon or silicon oxide during the first etch step.

[0004] In yet another embodiment, a wet chemical processing system is provided. The wet chemical processing system may comprise a chamber configured to receive a substrate and expose the substrate to a wet etch chemical composition, a chemical supply system coupled to the chamber, the chemical supply system supplying the wet etch chemical composition to the chamber, and a controller configured to control components of the wet chemical processing system to execute the techniques described herein.

[0004a] In one aspect, there is provided a method for etching features formed on a substrate, comprising providing a substrate having a high aspect ratio structure comprised of a first set of exposed features comprising silicon nitride, and a second set of exposed features comprising silicon or silicon oxide; loading the substrate into a wet chemical processing system; performing a first etch step comprised of exposing the substrate to a wet etch solution of phosphoric acid to selectively remove at least part of the silicon nitride from the high aspect ratio structure, wherein a hydrolysis reaction creates a silica reaction product in the wet etch solution from the silicon nitride, wherein at least a portion of the silica reaction product deposits on the silicon or silicon oxide of the high aspect ratio structure; and performing a second etch step comprised of further exposing the substrate to the wet etch solution of phosphoric acid to remove at least some of the deposited silica reaction product

from the silicon or silicon oxide by dissolving the deposited silica reaction back into the wet etch solution of phosphoric acid,wherein the first etch step is performed until a concentration of silica reaction product in the wet etch solution of phosphoric acid decreases due to depletion of the silicon nitride available for the hydrolysis reaction, and wherein the second etch step is performed continuously after performing the first etch step by continuously exposing the substrate to the wet etch solution of phosphoric acid and uses the decreased concentration of silica reaction product in the wet etch solution to reverse the hydrolysis reaction and dissolve the deposited silica reaction product back into the wet etch solution of phosphoric acid.

[0004b] In another aspect, there is provided a method for etching features formed on a substrate, comprising providing a substrate having a high aspect ratio structure with an aspect ratio of at least 4:1 comprised of a first set of exposed features comprising silicon nitride, and a second set of exposed features comprising silicon or silicon oxide; loading the substrate into a wet chemical processing system; exposing the substrate to a wet etch solution of phosphoric acid to generate a chemical etching reaction for a first time duration to selectively remove at least part of the silicon nitride from the high aspect ratio structure, wherein during the first time duration a concentration of silica in the wet etch solution from the chemical etching reaction initially increases and a hydrolysis reaction occurs that forms a colloidal silica reaction product that deposits on the silicon or silicon oxide of the high aspect ratio structure, and wherein the first time duration ends when the concentration of silica decreases in the wet etch solution due to depletion of silicon nitride available for the chemical etching reaction; after the first time duration, continuing exposing the substrate to the wet etch solution of phosphoric acid for a second time duration to reverse the hydrolysis reaction thereby dissolving the deposited silica reaction product back into the wet etch solution of phosphoric acid to preferentially remove substantially all of the deposited colloidal silica reaction product from the silicon or silicon oxide without etching the silicon or silicon oxide; and monitoring a concentration of silica, silicon or a silicon-containing compound in the wet etch solution using a chemical monitoring system included in the wet chemical processing system to determine completion of the first and second time durations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A more complete understanding of the present inventions and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, in which like reference numbers indicate like features. It is to be noted, however, that the accompanying drawings illustrate only exemplary embodiments of the disclosed concepts and are therefore not to be considered limiting of the scope, for the disclosed concepts may admit to other equally effective embodiments.

[0006] Figures 1A-1E illustrate cross-section views of an exemplary semiconductor structure having silicon nitride to be removed and the formation and removal of silica deposits on the semiconductor structure.

What is claimed is:

1. A method for etching features formed on a substrate, comprising:

providing a substrate having a high aspect ratio structure comprised of a first set of exposed features comprising silicon nitride, and a second set of exposed features comprising silicon or silicon oxide;

loading the substrate into a wet chemical processing system;

performing a first etch step comprised of exposing the substrate to a wet etch solution of phosphoric acid to selectively remove at least part of the silicon nitride from the high aspect ratio structure, wherein a hydrolysis reaction creates a silica reaction product in the wet etch solution from the silicon nitride, wherein at least a portion of the silica reaction product deposits on the silicon or silicon oxide of the high aspect ratio structure; and

performing a second etch step comprised of further exposing the substrate to the wet etch solution of phosphoric acid to remove at least some of the deposited silica reaction product from the silicon or silicon oxide by dissolving the deposited silica reaction back into the wet etch solution of phosphoric acid,

wherein the first etch step is performed until a concentration of silica reaction product in the wet etch solution of phosphoric acid decreases due to depletion of the silicon nitride available for the hydrolysis reaction, and wherein the second etch step is performed continuously after performing the first etch step by continuously exposing the substrate to the wet etch solution of phosphoric acid and uses the decreased concentration of silica reaction product in the wet etch solution to reverse the hydrolysis reaction and dissolve the deposited silica reaction product back into the wet etch solution of phosphoric acid.

2. The method of claim 1, wherein the second etch step is a silicon nitride overetch step.

3. The method of claim 2, wherein the second etch step is an overetch step in a range of approximately 5%-40%.

4. The method of claim 3, wherein the second etch step is an overetch step in a range of approximately 15%-30%.

5. The method of claim 1, further comprising:

monitoring a concentration of at least one chemical constituent of the wet etch solution during the first etch step using a chemical monitoring system included in the wet chemical processing system.

6. The method of claim 1, further comprising:

monitoring a concentration of at least one chemical constituent of the wet etch solution during the second etch step using a chemical monitoring system included in the wet chemical processing system.

7. The method of claim 1, wherein at least one parameter of the first etch step or the second etch step is selected such that substantially all of the deposited silica reaction product formed on exposed features comprising silicon or silicon dioxide during the first etch step is removed during the second etch step.

8. The method of claim 7, wherein the at least one parameter is selected from a group consisting of duration of the first etch step, duration of the second etch step, concentration of at least one chemical constituent of the wet etch solution during the first etch step, concentration of at least one chemical constituent of the wet etch solution during the second etch step, temperature of the wet etch solution during the first etch step, temperature of the wet etch solution during the second etch step, flow rate of the wet etch solution during the first etch step, and flow rate of the wet etch solution during the second etch step.

9. The method of claim 1, wherein the wet chemical processing system is a single substrate processing system.

10. The method of claim 1, where in the wet chemical processing system is configured to process a plurality of substrates at the same time.

11. The method of claim 1 wherein a maximum silicon nitride to silicon oxide etch selectivity during the first etch step is higher than the silicon nitride to silicon oxide etch selectivity during at least a portion of the second etch step.

12. The method of claim 1, further comprising:

monitoring a concentration of silica, silicon or a silicon-containing compound in the wet etch solution during the first and second etch steps using a chemical monitoring system included in the wet chemical processing system.

13. The method of claim 1, wherein the wet etch solution of phosphoric acid is at a temperature of 140° C to 170° C when the first and second wet etch steps are performed.

14. The method of claim 1, wherein the wet etch solution of phosphoric acid is 70 wt % to 95 wt % phosphoric acid.

15. The method of claim 1, wherein the wet etch solution of phosphoric acid is at a temperature of 140° C. to 170° C. when the first and second wet etch steps are performed and the wet etch solution of phosphoric acid is 70 wt % to 95 wt % phosphoric acid.

16. A method for etching features formed on a substrate, comprising:

providing a substrate having a high aspect ratio structure with an aspect ratio of at least 4:1 comprised of a first set of exposed features comprising silicon nitride, and a second set of exposed features comprising silicon or silicon oxide;

loading the substrate into a wet chemical processing system;

exposing the substrate to a wet etch solution of phosphoric acid to generate a chemical etching reaction for a first time duration to selectively remove at least part of the silicon nitride from the high aspect ratio structure, wherein during the first time duration a concentration of silica in the wet etch solution from the chemical etching reaction initially increases and a hydrolysis reaction occurs that forms a colloidal silica reaction product that deposits on the silicon or silicon oxide of the high aspect ratio structure, and wherein the first time duration ends when the concentration of silica decreases in the wet etch solution due to depletion of silicon nitride available for the chemical etching reaction;

after the first time duration, continuing exposing the substrate to the wet etch solution of phosphoric acid for a second time duration to reverse the hydrolysis reaction thereby dissolving the deposited silica reaction product back into the wet etch solution of phosphoric acid to preferentially remove substantially all of the deposited colloidal silica reaction product from the silicon or silicon oxide without etching the silicon or silicon oxide; and

pmonitoring a concentration of silica, silicon or a silicon-containing compound in the wet etch solution using a chemical monitoring system included in the wet chemical processing system to determine completion of the first and second time durations.

17. The method of claim 16 wherein a maximum silicon nitride to silicon oxide etch selectivity during the first time duration is higher than the silicon nitride to silicon oxide etch selectivity during the second time duration.

18. The method of claim 16 wherein the wet etch solution of phosphoric acid is at a temperature of 140° C. to 170° C. for the first time and second time duration.

19. The method of claim 16 wherein the wet etch solution of phosphoric acid is 70 wt % to 95 wt % phosphoric acid.

20. The method of claim 16 wherein the wet etch solution of phosphoric acid is at a temperature of 140° C. to 170° C. for the first time and second time duration and the wet etch solution of phosphoric acid is 70 wt % to 95 wt % phosphoric acid.